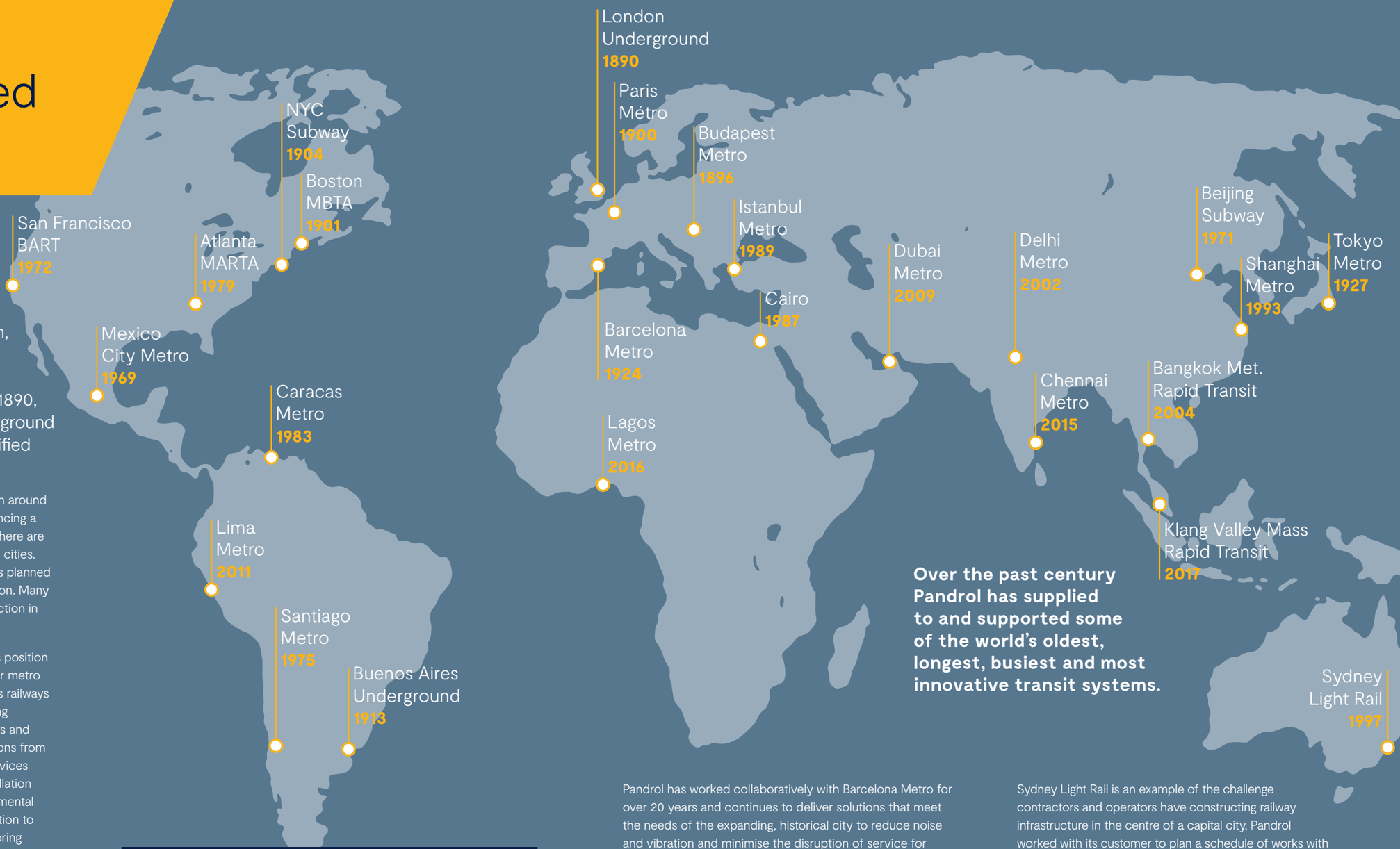
Underpinning unprecedented urban growth



The Metropolitan Railway, now part of the London Underground system, was the first underground urban railway in the world when it opened under steam power in 1863. And in 1890, parts of what is now London Underground also became the world's first electrified underground railway.

Although underground and other light rail has been around for well over a century now, it is currently experiencing a resurgence of growth, particularly in Asia, where there are large, rapidly expanding populations in developing cities. India, for example, currently has 30 metro projects planned in its cities that have populations of over one million. Many urban transit systems are currently under construction in other parts of the Far East.

Over the past 20 years, Pandrol has developed its position as a global leader of rail infrastructure solutions for metro and light rail, with its systems installed in numerous railways throughout the world. Designing and manufacturing fastening systems, welding, electrification solutions and track equipment, Pandrol can offer multiple solutions from a single supplier. The company's products and services are designed to maximise efficiency of track installation and operation, and to address safety and environmental factors such as noise and vibration. A recent addition to the Pandrol service offering is track-based monitoring equipment which generates data that is then analysed using Pandrol innovative systems.

This offers customers insight into their metro and underground tracks that can be used to prevent maintenance needs occurring and maximise uptime.

The following metro feature looks at recent projects that Pandrol has delivered globally. Each project presented unique product and environmental requirements that the Pandrol team, in collaboration with their customers, worked to meet.

"Pandrol's teams are rail infrastructure experts, encouraging customers to collaborate to solve their problems and work together from design through to installation and beyond.

Thomas Lorent / Head of Transit

Over the past century Pandrol has supplied to and supported some of the world's oldest, longest, busiest and most innovative transit systems.

Pandrol has worked collaboratively with Barcelona Metro for over 20 years and continues to deliver solutions that meet the needs of the expanding, historical city to reduce noise and vibration and minimise the disruption of service for maintenance. For the Line 5 Barcelona Metro project Pandrol was asked to develop a solution that could offer the same high performance as the current system but was lighter, more ergonomic and quicker to install.

The priority for Santiago Metro is keeping the city moving, this is increasingly challenging as the city experiences regular disruptions to service following earthquakes. Pandrol worked in partnership to develop a value engineered solution that could offer reliability in extreme conditions.

Sydney Light Rail is an example of the challenge contractors and operators have constructing railway infrastructure in the centre of a capital city. Pandrol worked with its customer to plan a schedule of works with minimal interruption to one of the busiest intersections in downtown Sydney enabling residents to live and work side by side with the transport system.

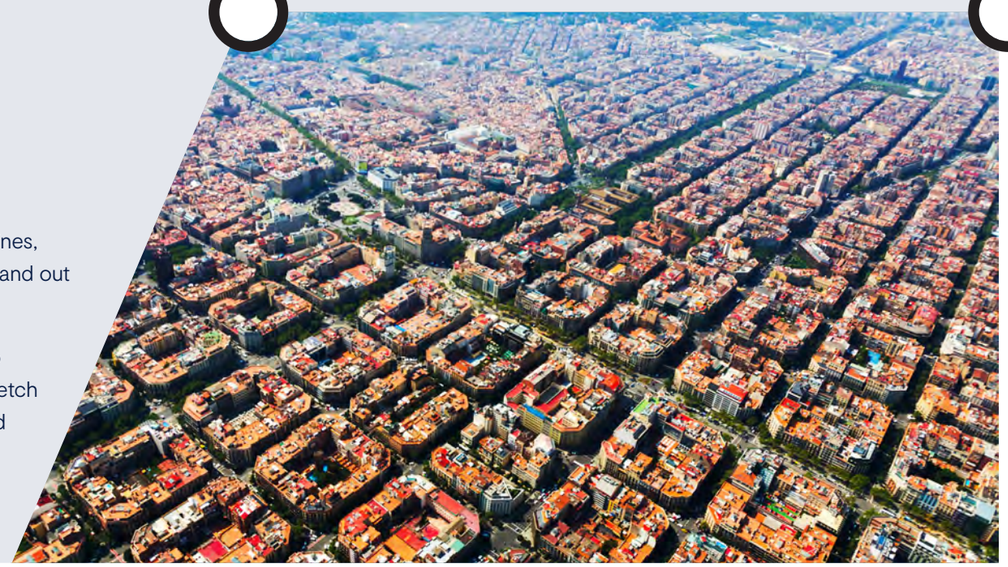
The Klang Valley Mass Rapid Transit project in Malaysia started for Pandrol as a series of site visits to analyse the projects varying requirements for noise and vibration isolation. Pandrol's technical team worked in collaboration with Mitsubishi Heavy Industries to design, test and deliver products with a comprehensive package of technical support that included working with local teams on track during construction to ensure best practice.

Barcelona

Pandrol makes light work of Line 5 for Barcelona Metro

The Barcelona Metro is an extensive network of 12 lines, which run mostly underground in central Barcelona and out into the city's suburbs.

Pandrol first worked with Metro Barcelona in 1997 to supply precast Floating Slab Track along a 14 km stretch where specific noise and vibration requirements had to be met.



New lightweight concrete block installed with VIPA fastening

Lightweight concrete block delivered pre-assembled

Completed installation for Barcelona Metro

> The fact that Pandrol's VIPA DFC was delivered to track side fully assembled made installation very efficient.
>
> **John Porrill** / Head of New Product Development

In total, Barcelona Metro has now worked with Pandrol for over 20 years because of the proven performance of its track fastening systems and the ongoing technical and site support that it provides. As part of a collaborative approach, both organisations work closely on new product developments, with a strong focus on safety and efficiency of installation.

Barcelona Metro has an ongoing programme of maintenance and improvement on its 120 km of track. Key areas of focus for Barcelona Metro are extending responsive maintenance intervals and making further improvements to noise and vibration levels within the large city area covered by its network. So work encompasses the replacement of track and sleepers that have reached the end of their service life, and in areas where an improvement in performance is now required – for example to reduce ground vibration. Safety is the main priority for the company.

> The VIPA DFC system is light enough to be handled by one person, which, combined with its ability to fit in the existing slab cavities, made it a very cost effective solution.
>
> from Barcelona Metro

→ THE CHALLENGE

Barcelona Metro was one of the first to benefit from a new Pandrol fastening system during refurbishment of Line 5 in 2017. The line required a retrofit to replace the existing booted sleeper blocks, because these had reached the end of their service life and were no longer performing as designed. The old sleeper blocks had also experienced corrosion problems in the tie bar.

Pandrol supplied its new light weight block solution to replace old booted sleeper blocks. The existing twin block system was first to be removed, leaving pockets in the slab. The new system would have to be installed into these pockets and would need to provide a stiffness similar to the performance of new booted sleepers. The concept was that in the new system, the required resilience would be provided above two individual blocks, rather than through a direct replacement for the boots that surround and support each end of the old twin-block sleepers. This puts the resilient elements where they are easier to inspect and maintain. The new individual blocks are smaller and easier to handle and can be rigidly grouted into place.

The Pandrol VIPA DFC fastening system, designed specifically for use on slab track, was selected. It is light in weight and has a small footprint that fits easily onto the new block. In total, 400 assemblies were supplied on this project. The Pandrol VIPA DFC System is optimised for use in pre-cast blocks, sleepers and slabs. It offers a cost effective, high performance solution for track where vibration ground borne noise mitigation is required.

→ INSTALLATION

Line 5 project demonstrated the methodology of installation of the new lightweight concrete block system in combination with the VIPA DFC fastening. Each block was placed into the empty pocket, the existing rails were lowered, and the Pandrol Fastclips were switched from the parked to the installed position using hand tools. Even with the pre-assembled VIPA DFC fastenings already fitted to them, the new blocks were light and safe enough to be handled by one person. This new low stiffness system provided an innovative solution for Barcelona Metro.

The lightweight concrete blocks were delivered to the worksite fully pre-assembled. The block is of the minimum size required to support and anchor the fastening assembly system, allowing it to be easily manipulated into position and attached to the rail prior to final adjustment and fixing. Reinforcement and anchor elements protrude from the underside of the block and are designed to tie it into concrete poured into the pocket around it to form the completed slab. The contractors carried out the fine track alignment before pouring the concrete to complete the installation.

Aided by pre-assembly off-site, the installation was simple and efficient, allowing the contractor to recover time lost on other sections of the job.

Throughout the project there was ongoing collaborative working between the Pandrol New Product Development team based in the UK and the local technical and customer liaison teams based in Spain. Together, they provided a full package of technical support and assistance during the installation. Pandrol also worked closely with the Polytechnic University of Catalonia to complete the block design calculations.

As a result of the successful delivery of this project, the Pandrol New Product Development team is now working on developments that enable even quicker installation on track. This is of particular interest to Barcelona Metro.

Further installations of the VIPA DFC system are planned. In particular, it will be used in the tunnel sections on the new Follobanen line in Norway.

Increasing welding productivity

Pandrol also supplied the innovative One-Shot crucible and induced air plus propane preheat, to support the Spanish PLR welding process used on Barcelona Metro.

This solution both increases levels of productivity and reduces the possibility of errors in the welding works due to the very simple preheating system which minimises the possibility of human error.

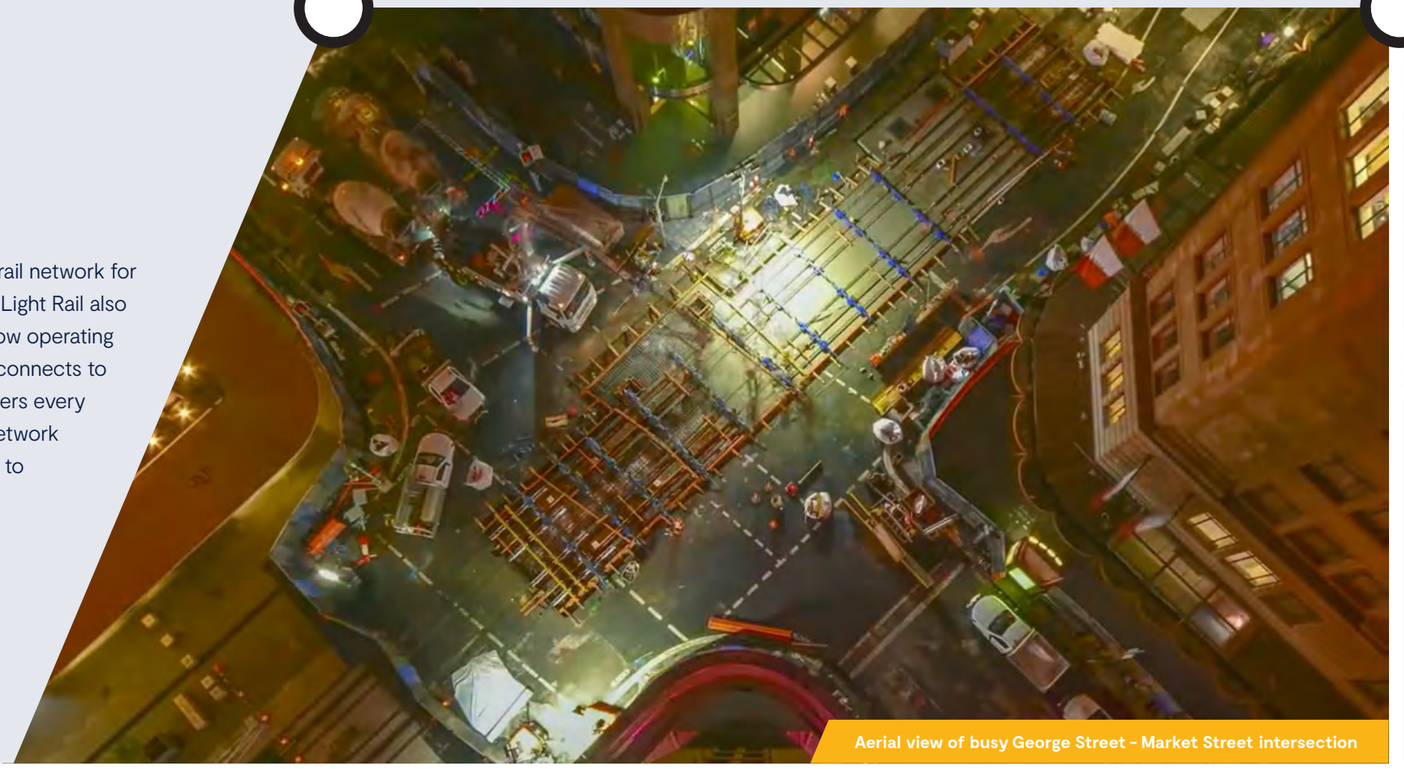
Pandrol worked with the welding contractor to ensure supplies were delivered practically "just in time" as it is very difficult for the welding team to store the materials on site.

Sydney

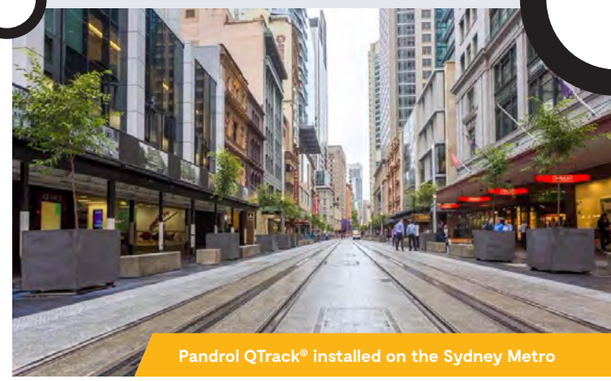
Pandrol's double solution for the Sydney Tramway

The CBD and South East Light Rail is a new light rail network for Sydney, with a 12 km route and 19 stops. Sydney Light Rail also incorporates the Inner West Light Rail which is now operating as the L1 Dulwich Hill Line – a 12.7 km route that connects to Central Station and is used by 9.8 million customers every year. It is expected that the expanded light rail network will significantly improve public transport access to major sporting and entertainment facilities.

The new line will serve the busiest areas in downtown Sydney from Circular Quay at the northern end of the Central Business District along George St and to the south-eastern suburbs of Randwick and Kingsford.



Aerial view of busy George Street - Market Street intersection



Pandrol QTrack® installed on the Sydney Metro

→ CONCLUSION

This was a high volume, demanding project, with great flexibility required in the planning process. The successful conclusion of the project demonstrates Pandrol's innovative approach to working proactively with the customer, and delivering high volumes to meet project requirements.

→ THE CHALLENGE

Due to its central location, the project required an innovative and flexible approach, including the necessity of a fast and forward installation taking place over weekends which could guarantee a minimum of interruption of the busy streets. Pandrol was appointed to this project in 2016, working alongside infrastructure contractor Acciona.

The main technical challenges lay in the need of mitigating the ground borne vibration issues of a project located in the Central Business District of Sidney, and the high electrical stray current isolation that was required.

A further requirement challenge was the high demand for large volumes and the need for great flexibility in the delivery programme. This challenge was met by Pandrol increasing factory production capacity, establishing several production moulds to work in parallel with each other.

→ SOLUTION

Pandrol solved these challenging project requirements by engineering a combined solution of two systems: Pandrol Qtrack® and Pandrol floating slab mats (FSM) which provided the perfect solution for work in a congested urban environment.

Pandrol was chosen because of the company's high capacity for production – required on such a large volume project and also because of Pandrol's extensive global experience and the confidence of Acciona in its products.

The Pandrol QTrack® system was specified for the Sydney Tramway, which is a continuously supported and fastened embedded slab track system. The rail is encapsulated by elastic resin bonded rubber profiles providing a broad range of benefits, such as vibration mitigation and electrical isolation, which was especially important for this project. Pandrol has developed a specialist solution to issues with stray current named QT ELEC. The QT ELEC is an electrical insulating film used on the Sydney tramway project.

Pandrol QTrack® is renowned for being easy to install and the Pandrol team provided technical support throughout the process, from design to installation stage. On-site training was also provided by the Pandrol team from Hoeilaart, in Belgium.

The system is widely recognised as a cost effective and long-lasting performance solution. It is consistent with the need to reduce ground-borne noise and vibration, and is compatible with special track works such as drainage and electrical boxes, insulation joints, axle counters, switches and crossings, and other typical depot equipment. It is compatible with the need for sustainability as it includes few components and is therefore eco-friendly. Pandrol QTrack® is renowned for being durable and maintenance-free and offers reduced life cycle costs. It is available for grooved and Vignola rails for different axle loads: LRT, Metro, Train, High Speed and Heavy Haul.

Pandrol QTrack® system was supplied in two different versions: XP and HP. XP covered the larger amount of track, almost 19 kilometres, where as the HP version of QTrack® was used over 10 kilometres.

Pandrol FSM was also specified in FSM-L13 and FSM-L4.5 systems, adapting to the level of vibration mitigation required by the project.

HP variation for LRT

XP variation for LRT

Kuala Lumpur

The first phase of the Klang Valley Mass Rapid Transit (KVMRT) project in Kuala Lumpur was recently completed. Here Pandrol developed and delivered the fastening systems for the 51 km Sungai Buloh to Kajang Line.

The line starts at Sungai Buloh, located to the north-west of Kuala Lumpur and runs through the city centre of Malaysia's capital city before ending in Kajang, a fast-developing town to the south-east of the city.

Following a competitive tendering process, Mitsubishi Heavy Industries (MHI) worked with Pandrol to propose compliant and cost effective solutions to the client. Pandrol's technical team recommended its VIPA DRS fastening system for the mainline areas while its Vanguard system is used in specific areas. Both systems are designed to control of rail roll on curves, but the lower dynamic stiffness that the Pandrol Vanguard system provides an even greater level of attenuation of transmitted vibrations. Pandrol also delivered an integrated third rail solution which provides 750V DC power supply.

Bringing power to the track

Through its joint venture company Railtech Alu Singen, Pandrol worked with MHI to develop and design the third rail system ensuring all interfaces, including rolling stock, track works, power supply and civil works, were considered.

The system supplied by Pandrol focused on coextruded rail technology which has two key benefits when applied to conductor rail solutions. Firstly, 100% of the stainless-steel strip is efficient, meaning it can be fully worn down to 0mm without any monitoring. A further benefit of the coextruded process is that there is no delamination of stainless-steel strip even if it becomes partially worn. These benefits add lifetime value to the railway through reliability and maintenance savings.

Pandrol takes pride in its history, expertise and commitment to quality. All components supplied are tested in in-house testing facilities and in external laboratories for specific test requirements. All tests are performed in accordance to Third Rail System technical specification, calculation notes results and international standards. To ensure a smooth and efficient installation, Pandrol supported the project by delivering installation, maintenance training and supervision on site.

Pandrol third rail system

The completed KVMRT Metro features:

- 51 km of track
- 400,000 passenger per day
- 80 km/h designed maximum speed
- Rail type 60E1 (mainline) EN 50E1 (depot)

The VIPA DRS fastening system is well proven in many metro projects worldwide. It offers a low vertical dynamic stiffness that leads to good levels of vibration isolation, and the proven technology of the Pandrol e-Clip. The baseplate system is easy to maintain and provides vertical and lateral adjustment capability.

As this was the first deployment of Vanguard in Malaysia, the Pandrol technical team supported the local team on-site with demonstrations on how to install and maintain this fastener.

The completed project will serve a local population estimated at 1.2 million people and is expected to carry approximately 400,000 passengers on four-car driverless trains, each with a capacity of 1200 people.

Andy Slowe /
Product support Engineer

By its nature, metro tracks in tunnels or on viaducts can be more complex to install than ballast track on an open site. Pandrol's technical team can advise on different construction methods, such as top-down wet pour, use of embedded blocks or sleepers, or pre-cast plinths or slabs. Pandrol products can offer a wide range of stiffnesses and adjustment capabilities.

This is just one in a series of recent and current metro projects that Pandrol has delivered in Asia, such as two large underground schemes, DTL and TSL, in Singapore, the Ho Chi Minh City Metro in Vietnam, the Red Line in Thailand, and Jakarta Metro in Indonesia.

Pandrol focuses its innovation on quality, safety and cost, which is why metro customers choose the company to design and manufacture new rail engineering technology. Pandrol's aim is to generate increased productivity, reduced possession times and achieve improvements to railway and worker safety. Over the years, the company has developed a wide range of transit products to suit the diverse range of requirements set by rail authorities and contractors, adapting these to satisfy local, regional and global standards.

Using its technical expertise and dedicated product support teams, Pandrol can address specific design considerations, for example in relation to track structure interaction, corrosion protection, special track work, adjustability requirements, and many other particular needs of the client or contractor.

> Pandrol's continued involvement and technical support on this project is greatly appreciated. The solution met the requirements presented by some significant challenges where areas of track are subject to high vibration sensitivity and require a more innovative approach.
>
> **Mr Ito** / KVMRT Trackworks Project Manager from MHI

→ SOLUTIONS PROVIDER /

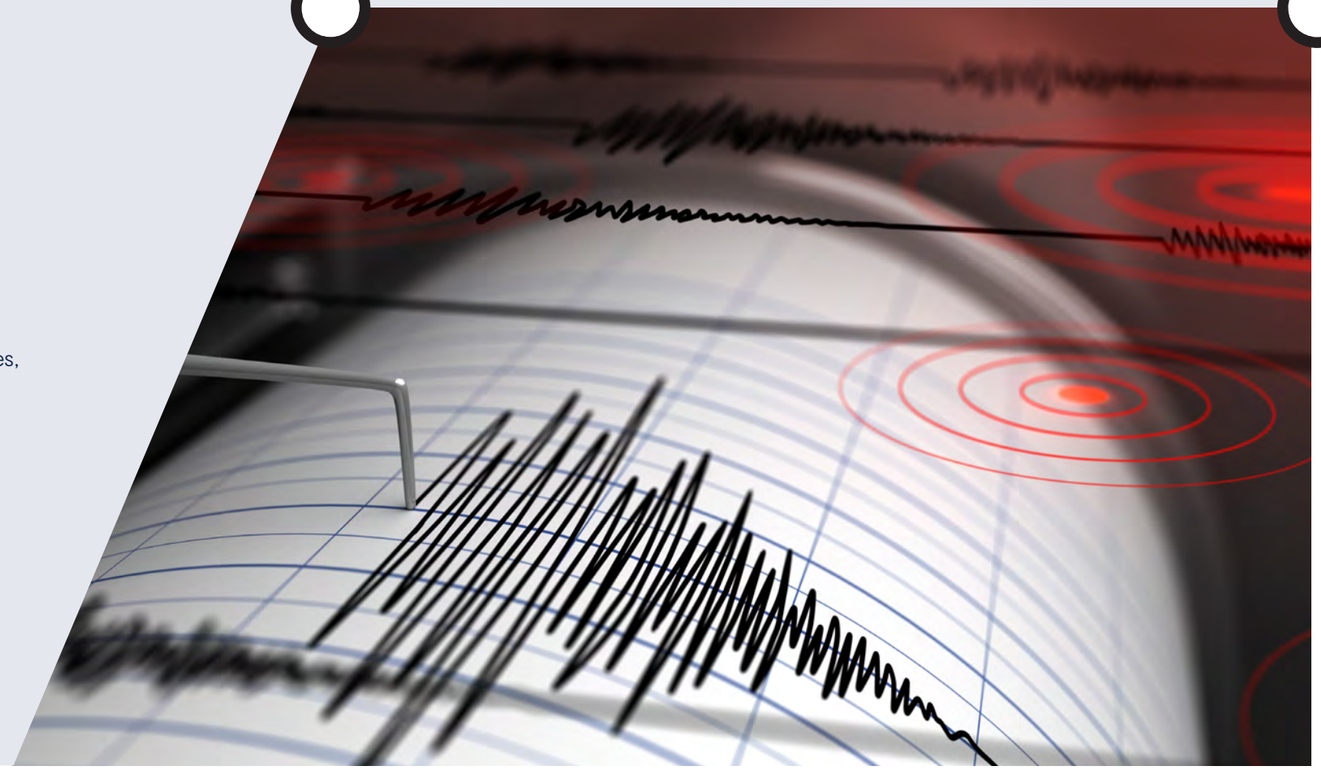
Pandrol's technical team often work with customers during the construction of metro lines because of the specific site challenges. As a complete solutions provider, Pandrol can offer the design, manufacture and implementation of fastenings, welding, equipment and electrification technologies, and can provide its renowned technical support in all these areas.

Santiago

Engineering a solution in an earthquake zone

Santiago Metro (Metro de Santiago) is one of the largest and most advanced underground railway networks in Latin America. It currently has six lines, 107 stations, running across 118 km and carrying around 2.5 million passengers every day.

Pandrol currently has a package of work which is part of a 20 year contract for the construction and maintenance of lines 3 and 6.



Santiago Metro

SEE-SD System

→ THE CHALLENGE

As Santiago is one of the locations in the world where earthquakes are most prevalent, the customer required a fastening solution that allowed for potential future adjustment of the track. In the last 12 months, there have been 67 earthquakes in Santiago, therefore the project requirements were for a +30 mm adjustment capability. The project required a fastening solution for 50 km of track and the requirements were for a lightweight baseplate and under-the-track rubber mats for noise and vibration mitigation.

→ SOLUTION

Pandrol delivered a multifaceted track solution including fastenings, catenary and floating slab mats. The unique and challenging requirements led to Pandrol developing a new composite plastic baseplate, the SEE-SD. This baseplate is designed to be embedded into fresh concrete or by wet pour methods. This would be more cost effective than a traditional aluminium/steel casting and would be easier to handle and install on the track. The SEE-SD provides adequate resilience (stiffness) to attenuate to the concrete slab and provides large vertical adjustments to the rail position. The Pandrol air evacuation system prevents trapped air entering under the baseplate. The SEE-SD plastic baseplate has a special feature of vents and channels that optimise insertion into concrete and ensures excellent resistance to lateral forces.

Once the system was developed, Pandrol's technical team carried out rigorous tests to demonstrate to the customer that their solution could meet both performance and cost requirements. This required technical validation of the system, including a complete and fully tested assessment of Pandrol's recommended solution.

The SEE-SD assembly is designed to give a typical vertical dynamic stiffness of around 60 MN/m. It offers a wide range of pad stiffness levels, making it suitable for meeting noise and vibration mitigation requirements on this project. It also meets all requirements of the latest updates of EN 13146 and EN 13481-5 standards. In addition, its performance relating to electrical insulation complies with EN 13146-5:2012.

The baseplates used in the SEE-SD design is made from glass fibre reinforced polyamide material in order to provide maximum resistance to lateral loads. The baseplate is not 'laid' on the concrete but 'anchored' and integrated into the slab. There is consequently no risk of slippage. The stress level in the screws is significantly reduced even on tight curves, as a result of the anchoring system, which is based on the use of two screws.

The SEE-SD was designed for use with the SD clip, with its screwed design that optimises track construction costs and provides very high technical performance. SD stands for 'safely driven' which relates to the controlled clip guidance from the 'parked' to the 'in-service' position.

SD insulated blocks are designed to offer lateral adjustment of the track gauge in increments of 1.25 mm. The method to adjust the gauge is managed simply by adapting the insulated block combination. SEE-SD meets the requirements for all urban rail networks, from tram lines to modern light rail and high capacity metro applications.

Over the lifetime of the project Pandrol has manufactured more than 200,000 SEE-SD fastenings systems to the French rail consortium ETF and Colas Rail on behalf of Metro de Santiago.

→ VIBRATION

To meet with vibration minimisation requirements, Pandrol supplied its Floating Slab Mats (FSM), which are continuous resilient mats used for the isolation of train-generated vibrations in concrete slabs. These FSMs are manufactured from high quality resin-bonded rubber to achieve vibration attenuation, with a low resonance frequency.

Pandrol QTrack® embedded rail system was also supplied to Santiago Metro depots to help in achieving a maintenance-free slab structure.

Rails were elastically supported and fastened while embedded providing free and safe movement of workers and maintenance vehicles. Pandrol QTrack® system can also be developed to completely encapsulate the switches and crossings of a depot in the same manner as a regular track.

→ ELECTRIFICATION

Electrification was a major part of the Santiago Metro project too, which was completed in 2017. Santiago Metro required 60 km of Rigid Catenary for this project, for which we designed and manufactured the whole system. This was supplied mainly for use within tunnels. Our rigid catenary system was specified as it offers low maintenance, high performance and enhanced safety.

The project involved providing technical support and training to the contractor installing the system. This included on-site training and members of our technical team were present during installation to ensure the process ran as smoothly as possible.

Rigid Catenary is an overhead contact system that has advantages over the third rail or suspended bimetallic T-rail. It is manufactured via an aluminium alloy profile, which accommodates the copper contact wire, with a great cross section for the current that allows operative OCS voltages from 750 to 1.500 V, without any feeding supply.

Rigid Catenary offers many advantages over traditional flexible catenary system, including no traction stress as it allows more contact wire wear without the risk of it breaking off. Rigid catenary provides no mechanical stress on the contact wire, so there is less wear and fewer maintenance issues.

Rigid Catenary

SUMMARY

It is common practice that in earthquake zones around the world, once an earthquake is detected, trains are immediately stopped, after which operation is continued at reduced speeds or is suspended, depending on the strength of the shock.

Metro de Santiago has invested in an infrastructure which mitigates the impact of frequent earthquake activity, whilst ensuring their long term performance and resilience. An 8.8 magnitude earthquake shook the southern part of Chile back in 2010 but the majority of the Metro survived well. More recently in April 2017, an earthquake of magnitude 7.1 reached Santiago after starting around the Chilean coast, whilst the Metro remained largely unaffected.